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Article

3D downscaling model for radar-based precipitation fields

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Abstract

The generating of rainfall fields with a higher resolution than so far observed and with realistic features is a challenge with multiple applications. In particular it could be useful to quantify the uncertainty introduced by the different sources of error affecting radar measurements, in a controlled simulation framework. This paper proposes a method to generate three-dimensional high-resolution rainfall fields based on downscaling meteorological radar data. The technique performs a scale analysis of the first radar tilt field combining a wavelet model with Fourier analysis. In order to downscale the upper radar elevations and with the aim of preserving the vertical structure, a homotopy of the observed vertical profiles of reflectivity is performed. Preliminary evaluation of the technique shows that it is able to generate realistic extreme values and, at the same time, partially reproduce the structure of small scales.

Zusammenfassung

Die Erzeugung von Niederschlagsfeldern mit realistischen Merkmalen und mit einer höheren Auflösung als beobachtete Felder ist eine Herausforderung mit vielfachen Anwendungen. Zum Beispiel ist es wichtig im Rahmen einer kontrollierten Simulation quantitativ die Unsicherheiten durch verschiedene Fehlerquellen zu bestimmen, die Messungen eines Wetterradars betreffen. Dieser Artikel schlägt eine Methode vor, dreidimensionale Niederschlagsfelder mit hoher Auflösung zu erzeugen basierend auf dem Downscaling von Radardaten. Die Technik realisiert eine maßstäbliche Analyse des Radarfeldes der untersten Elevation mit der Kombination eines Wavelet-Modells und einer Fourier-Analyse. Um höhere Radar-Elevationen herunter zu skalieren wird eine Homotopie der beobachteten Vertikalprofile der Reflektivität durchgeführt mit dem Ziel die vertikale Struktur zu erhalten. Die ersten Beurteilungen dieser Technik zeigen, dass diese imstande ist realistische Extremwerte zu erzeugen und gleichzeitig die Struktur in kleineren Skalen teilweise zu reproduzieren.

1 Introduction

High-resolution 3D rainfall fields may be very useful for some studies. In particular, they may be used as reference in simulation studies quantifying the uncertainty introduced by the different sources of error affecting radar measurements (e.g. Anagnostou and Krajewski, 1997; Borga et al., 1997; Zhang et al., 2004), and to assess the hydrological effects of these errors (Sánchez-Diezma et al., 2001; Sharif et al., 2002, 2004).

Traditionally, these rainfall fields have been obtained through two main approaches: 1) using pure stochastic rainfall models or 2) downscaling real precipitation measurements.

Stochastic models can provide a wide range of spatial and temporal rainfall patterns for many resolutions and with acceptable computational speed. The main problem involved in the stochastic simulation is the lack of physical consistency between atmospheric processes and the simulated rainfall fields.

On the other hand, for downscaling techniques, synthesizing rainfall fields with higher resolution than observed and reproducing the rainfall variability at all scales is quite a challenge due to the complexities of rainfall (Lanza et al., 2001). Typically, radar measurements (and also satellite imagery) have been used in this framework. A straightforward approximation to this problem is downscaling rainfall measurements by tri-linear interpolation (i.e. precipitation values of the 3D Cartesian high-resolution field are obtained through linear interpolation of the "n" closest neighbours, see Sánchez-Diezma, 2001). However, this technique does not preserve the real variability in the new created scales, which may be a significant limitation for some studies.

The first techniques introducing variability proposed to impose random noise to a given high-quality radar-rainfall field. Krajewski and Georgakakos (1985) changed the noise level from point to point depending on the local original field characteristics such as the magnitude and the horizontal gradient of reflectivity. During

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